Report for 2004MI52B: Sediment transport modeling using high resolution LIDAR-derived DEMs

- Other Publications:
  - C. P. Barber and A. M. Shortridge (2005a) Terrain representation, scale, and hydrologic modeling: does LiDAR make a difference? Invited Submission to Computers and Geographic Information Science, May 1, 2005.
  - C. P. Barber and A. M. Shortridge (2005b) Terrain representation, scale, and hydrologic modeling: does LiDAR make a difference? Autocarto 2005. Las Vegas, Nevada, March 21-23.
  - C. P. Barber and A. M. Shortridge (2004) Light Detection and Ranging (LiDAR) Derived Elevation Data for Surface Hydrology Applications. Institute of Water Research Technical Report IWR-1(2004), Michigan State University, East Lansing, Michigan. http://www.hydra.iwr.msu.edu/iwr/publications/index.asp

Report Follows

Project Number: 2004MI52B **Start Date:** 03/01/04 (actual)
FY 2004 Federal Funds: $15,000 **End Date:** 02/28/05 (actual)
FY 2004 Non-Federal Funds: $30,879

Title: Sediment transport modeling using high resolution LIDAR-derived DEMs
Investigator(s): Ashton Shortridge, Assistant Professor, Michigan State University
Co PI: Yi Shi, Research Assistant, Michigan State University
Focus Category: Methods, Non Point Pollution, Sediments
Descriptors: Scale, DEM, hydrologic model, accuracy, LIDAR
Congressional District: Eighth

Background

In the past few years high resolution, remotely sensed radar and laser-derived digital elevation models (DEMs) have moved from a promising technology to a primary means of base data development. The Shuttle Radar Topography Mission (SRTM), flown in early 2000, has yielded terrain data across much of the globe NASA (2005). Far higher resolution data (sub 3 meter horizontal resolution) has been collected from laser sensors collecting data via LIDAR (light detection and ranging) mounted in aircraft (Sapeta, 2000); some of this data is publically available via the internet. Due to its high spatial resolution, relatively inexpensive production cost, and rapid processing, it is anticipated that much or all of the United States will be covered by high resolution DEMs derived from this technology within a decade (see e.g. FEMA, 2005).

Digital elevation models are a primary input source for developing and parameterizing a range of hydrologic modeling applications (Hutchinson & Gallant, 1999; Moore et al., 1991). The implications for modeling erosion and sediment load are profound, since the spatial resolution of this data is an order of magnitude finer than the best available for much of the country, including Michigan. In theory, this should lead to tremendous improvements in our ability to determine key spatial hydrological parameters like flow vectors, which in turn should enable a high degree of precision in specifying the dynamics of transport in surface water flow.

However, important questions remain. No DEM is without error, and it is not straightforward to translate a data quality report into a clear understanding of how data error will affect a given application (Heuvelink et al., 1989). Studies into specific DEM products have revealed numerous problems (eg. Bolstad & Stowe, 1994), and terrain derivative datasets critical for surface hydrology applications are known to be highly sensitive to scale factors and error (Garbrecht & Starks, 1995; Zhang & Montgomery, 1994). How well do LIDAR-derived DEMs depict terrain derivatives important for water-related applications? Are these products truly “bare-earth”, meaning that they depict the way that water flows across it, or are they affected by vegetation and human constructions? Perhaps most importantly, will the low relief typical of Michigan watersheds confound sediment transport modeling applications, even employing high resolution, high accuracy DEMs? Recent research has begun to consider these questions (Raber, 2003), but clear answers have not emerged.

Project Objectives

In light of these important questions, we proposed to conduct a comparative study to evaluate the utility of LiDAR-derived DEMs for hydrologic modeling applications. Specifically, we wished to accomplish the following objectives:

1. Review recent literature on LiDAR DEM generation and quality
2. Identify and obtain high-resolution (sub-5 meter) LiDAR DEM data
3. Conduct a GIS-based hydrologic study and compare results using LiDAR and conventional medium-resolution products
4. Evaluate spatial resolution effects & production artifacts
5. Communicate findings via:
    1. a web presence
    2. major conference
    3. paper in an appropriate journal

Personnel

Dr. Ashton Shortridge, an assistant professor in the Department of Geography, wrote the original proposal, served as principal investigator. Mr. Chris Barber, a graduate student in the Forestry Department, worked as a graduate research assistant on this grant. Institute of Water Research staff and scientists supplied critical space, equipment, support, and suggestions.

Accomplishments

1. *Literature Review*

LiDAR DEM research is highly multidisciplinary, and results appear in diverse outlets. The first few months of the project were spent developing a bibliography of relevant work from this body of work, and preparing a technical report on results to date, along with some preliminary findings. This technical report, published in the Institute of Water Research series as WR-1 2004, is entitled, *Light Detection and Ranging (LiDAR) - Derived Elevation Data for Surface Hydrology Applications*. The report is available online.

2. *Obtaining high resolution LiDAR DEM data*

We had originally intended to identify a study area in Michigan with LiDAR and conventional sources. While considerable LiDAR data exists for the state, most of it is for areas immediately adjacent to the Great Lakes. Since the focus of this project is on watershed modeling, this was not adequate for our needs. We looked elsewhere and identified three free, publically available sources:

1. Puget Sound, Washington (from USGS, 2005)
2. North Carolina (North Carolina, 2005)
3. Louisiana (CADGIS, 2005)

We evaluated all three and settled on two watersheds in eastern North Carolina for subsequent research. These study regions were chosen due to their similarity to topography in Michigan. USGS 7.5”-series DEM data were obtained for these watersheds in addition to the LiDAR data. Details about the study region and the available data are included in the papers.

3. *Comparative GIS-based hydrological modeling study*
We conducted an intensive analysis on elevation data for the two watershed study regions in North Carolina. This work involved the calculation of many critical hydrologic parameters, like slope, flow direction, upstream contributing area, and basin delineation. Full results are reported in Barber & Shortridge (2005a).

4. *Evaluate spatial resolution effects & production artifacts*
This became the primary focus of the research. We found that, in comparison with conventional medium resolution DEM products, LiDAR data methods produced strikingly different results for certain hydrologic operations, such as basin delineation, in areas of low relief. Cell resolution alone did not explain this effect. Other operations were much more robust to the source of elevation or the resolution. A higher relief watershed showed only moderate sensitivity to basin delineation, indicating that these effects are very much dependent on the geography of the region in question. At the same time, postprocessing conducted by the producers of the North Carolina DEM data appeared to have successfully resolved potential artifacts like bridges and culverts. Full results are reported in Barber & Shortridge (2005a).

5. *Communicate findings*
We presented two brown-bag luncheon presentations at the Institute of Water Research on the campus of Michigan State University. The first of these, held in fall 2004, provided a review of the sources, production, strengths, and potential weaknesses of LiDAR-derived digital elevation data. The second of these, held in spring of 2005, documented our findings.

We published a technical report (Barber & Shortridge, 2004) that provided a review of LiDAR-based DEM data production methods, data characteristics, and applications. The report also indicated the potential of LiDAR data for hydrologic applications, but identified potential pitfalls to its use.

An abstract submitted to Autocarto 2005, a longstanding, prestigious international conference in geographic information science with a selective peer reviewed application process, was accepted for a full paper. We wrote the paper, which was published in the conference proceedings (Barber & Shortridge, 2005b). Chris Barber presented the paper in Las Vegas at the conference in March of 2005. Ours was one of a subset of papers from that conference that were invited for submission to a special issue of Computers and Geographic Information Science (CaGIS), an international journal with high standing in the field (Barber & Shortridge, 2005a). This manuscript, reworked extensively after the conference, is currently (late May, 2005) under review.

Opportunities and Challenges
There is no such thing as a standard LiDAR DEM. The final product is the result of a series of processing decisions, and its quality is a function of many factors. The Louisiana product mentioned previously in this report is subject to 'damming' artifacts, as it is essentially a straightforward surface model. Features such as bridges and culverts were not accounted for in postprocessing. As a result, standard hydrologic operations such as calculating flow directions can produce substantial 'ponded' areas. In contrast, the North Carolina product was edited with the use of USGS stream line data to remove such

features. This data was not subject to damming artifacts. Information about postprocessing decisions should be vital components of metadata for LiDAR DEMs; how to incorporate this seamlessly in spatial analysis such as hydrologic modeling applications remains an important research question.

We never quite got around to running a sediment transport model on these data. We decided against this because analyzing the sensitivity of terrain and derivatives like slope seemed most important. The addition of more variables for the sediment model (e.g. soil information) would have obscured the role of the topographic inputs and the sensitivity of elevation to resolution. The manuscript under review at CaGIS covers this material in detail; we have a much better understanding now of the role of these factors. One clear next step is to implement the RUSLE-based sediment model in a comparative analysis.

A profound issue for the production and dissemination of national elevation data was identified in this study. This issue concerns the USGS National Elevation Data (NED) product, which combines data from different sources to produce the seamless product (USGS, 2005). In this research, we found substantial discrepancies in basin delineation for the low-lying topography of the Neuse watershed. **These discrepancies appeared to be related to the source of the elevation data**, and were not moderated by resampling to 30 meters. The effect of data conflation in NED on sensitive derivatives like basin delineation is unclear but potentially significant. We advise researchers to consider the NED metadata carefully to determine if multiple sources have been mosaicked for their study regions, and suggest that further study is warranted on this issue.

Output

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